

# NAVAL AIR PROPULSION TEST CENTER

TRENTON, NEW JERSEY 08628

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TURBINE ENGINE FAILURES THAT OCCURRED IN  
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ROTOR BURST PROTECTION PROGRAM: STATISTICS ON AIRCRAFT  
GAS TURBINE ENGINE FAILURES THAT OCCURRED IN COMMERCIAL  
AVIATION DURING 1971

REPORT ON NASA DPR C-41581-B, MOD. 4

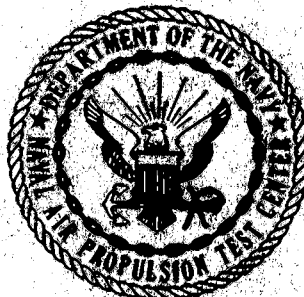
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13. ABSTRACT  This report presents statistical information relating to the number of gas turbine engine rotor failures which occurred during 1971 in commercial aviation service use. The number and types of rotor failures are categorized as contained and uncontained failures. The predominant failure involved blade fragments, 83 percent of which were contained. Although fewer rotor rim and disk failures occurred, all of the disk and 67 percent of the rim failures were uncontained. Design and life prediction problems accounted for almost 40 percent of the failures.			

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## INTRODUCTION

1. This report has been prepared as part of the Rotor Burst Protection Program (RBPP), which is sponsored by the National Aeronautics and Space Administration (NASA)<sup>1</sup> and conducted by the Naval Air Propulsion Test Center (NAPTC). The objective of the RBPP is to develop criteria for the design of devices that will be used on aircraft to protect passengers and the aircraft structure from the lethal and devastating fragments that are generated by gas turbine engine rotor bursts.
2. Presented in this report are statistics on gas turbine rotor failures that have occurred in commercial aviation during 1971. These statistics were compiled from the Flight Standards Mechanical Reliability Reports that are published by the Department of Transportation, Federal Aviation Administration (FAA). These data are analyzed to establish:
  - a. The incidence of contained and uncontained<sup>2</sup> rotor bursts.
  - b. The failure distribution with respect to engine component; i. e., fan, compressor or turbine.
  - c. The type of rotor fragment (disk, rim or blade) typically generated at failure.
  - d. The cause of failure.
  - e. The type of engine involved.

## RESULTS

3. The results of the analyses that were conducted using the FAA data are shown in Figures 1 to 4, inclusive.
  - a. Figure 1 shows that commercial aviation had experienced 124 rotor failures, 35 or 28% of which were uncontained. Although the number of uncontained failures is low compared to the 2604 shutdowns experienced by the gas turbine powered commercial air carrier fleet during 1971, the incidence is considered to be significantly high because of the catastrophic potential of such failures.

<sup>1</sup>NASA DPR C-41581-B, Mod. 4

<sup>2</sup>An uncontained rotor burst is defined as a rotor failure that produces fragments which penetrate and escape the confines of the engine casing.

b. Figure 2 shows the distribution of rotor failures according to the engine component involved--fan, compressor or turbine; the types of fragments that were generated; and the percentage of uncontained failures according to the type fragment generated. These data indicate that:

(1) An almost equal number of failures occurred in the compressor and turbine sections of the engines, corresponding to 45 and 43% of the failures, respectively, while 12% of the failures were experienced by the engine fan.

(2) Eighty-five percent of the failures involved blade fragments, 83% of which were contained. The remaining failures produced rim and disk fragments, 5 and 10%, respectively. While the rim and disk failures contributed a relatively small percentage of the total failures, all of the disk failures and approximately 67% of the rim failures were uncontained.

c. Figure 3 shows the rotor failure distribution among the types of engines that were affected and the total number of engines in use of the type that experienced rotor failures. These data indicate that the JT9D and ALL501 engines have experienced relatively high percentages of rotor failure. It is interesting to note that the JT9D engine is a relative newcomer to fleet service, while the ALL501 engine has been in service for quite some time.

d. Figure 4 shows the cause of the rotor failures experiences in 1971. The predominant causal factor was design and life prediction problems which accounted for almost 40% of the rotor failures that occurred.

#### CONCLUSIONS

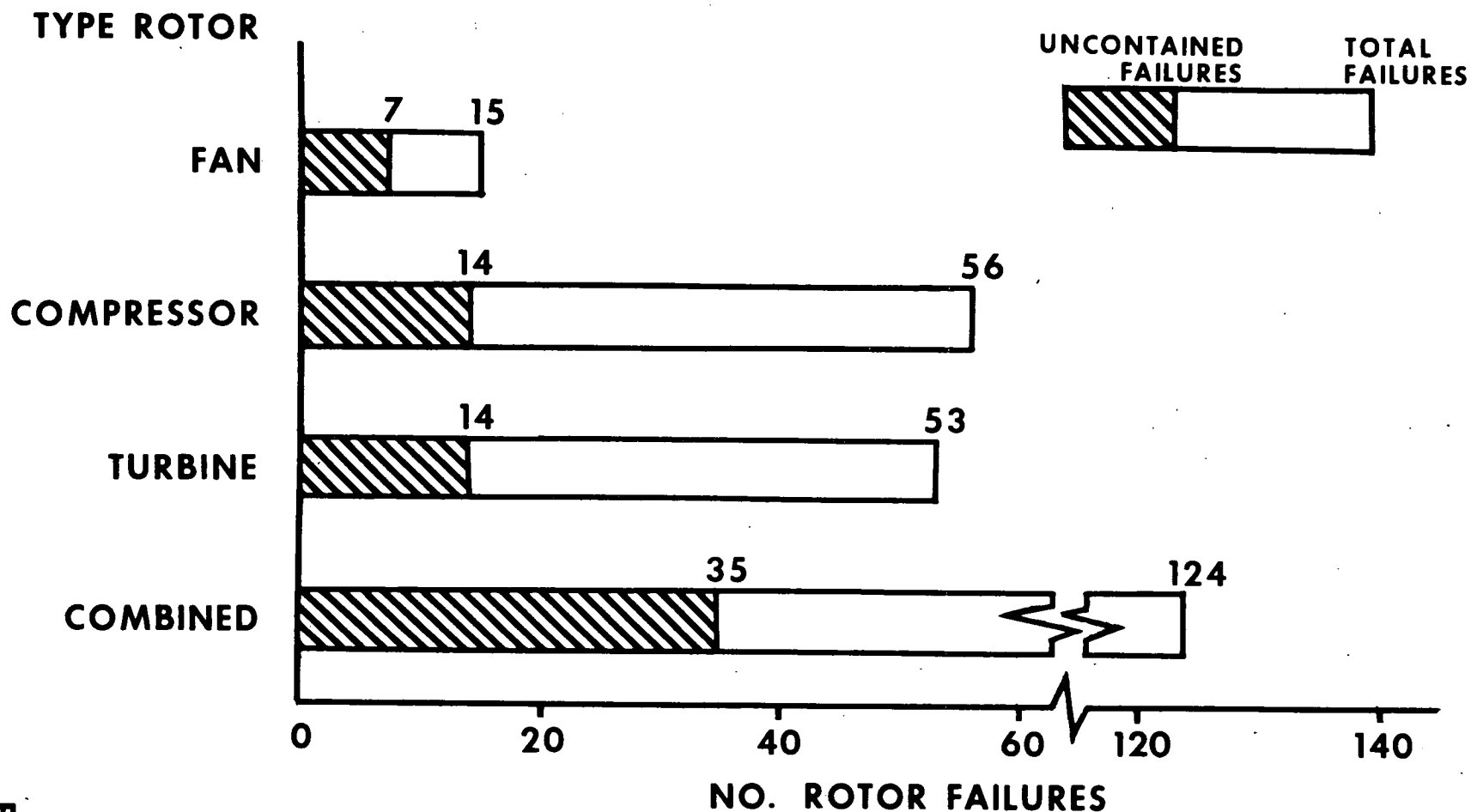
4. The incidence of uncontained rotor failure is still significantly high enough to warrant continuation of the experimental and analytical efforts that constitute the Rotor Burst Protection Program.

5. Of all the types of fragments generated at rotor failure, disk fragments continue to present the major threat to the welfare and safety of commercial aircraft passengers.

6. The number of uncontained blade failures is surprisingly high, when it is considered that a rotor blade containment requirement has been incorporated as part of the FAA regulations.

7. While the causes of rotor failure are many and varied, the inability to analytically predict structural performance characteristics of the rotors and other engine components with sufficient accuracy appears to be the main cause for rotor failure.

# INCIDENCE OF ROTOR FAILURE<sup>(1)</sup> IN COMMERCIAL AVIATION 1971



(1) defined as a failure that produces a fragment.

FIGURE 1

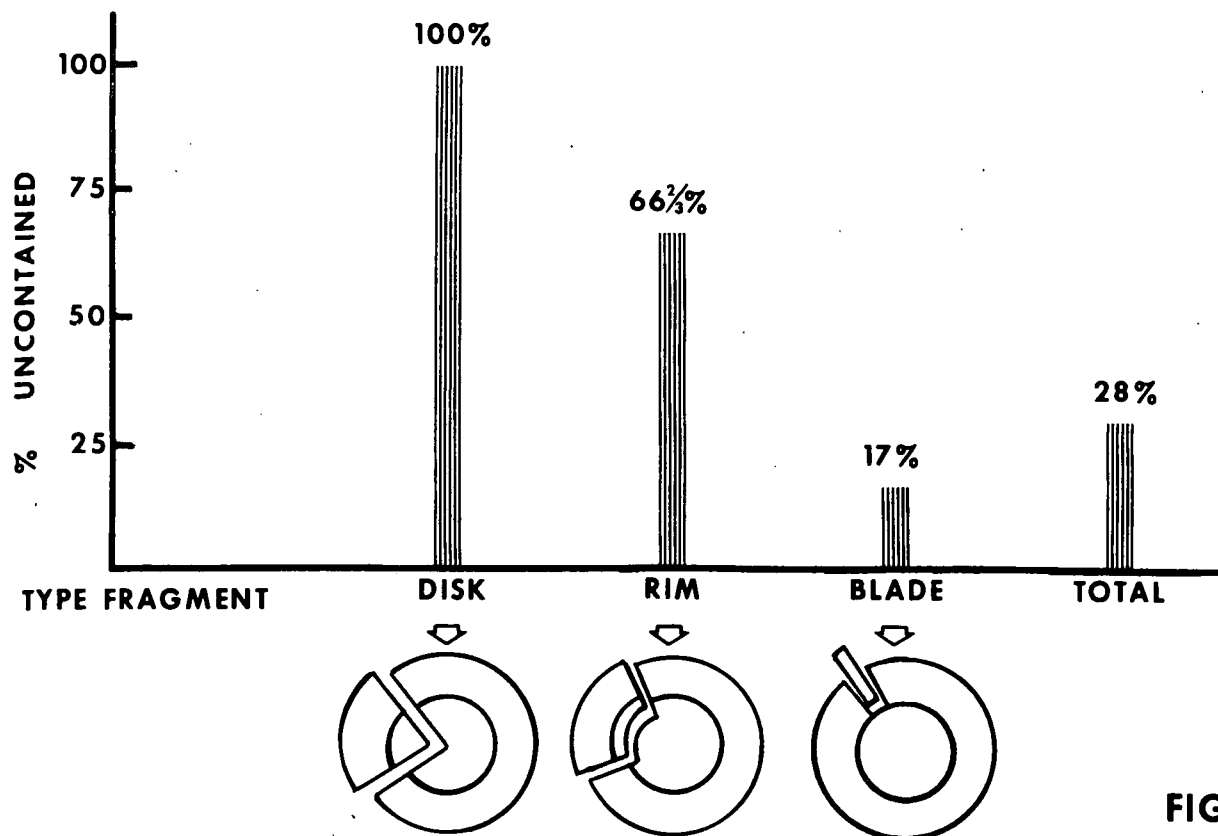


# **COMPONENT AND FRAGMENT TYPE DISTRIBUTIONS FOR TOTAL AND UNCONTAINED ROTOR FAILURES - 1971**

ENGINE ROTOR COMPONENT	TYPE OF FRAGMENT GENERATED						TOTALS	
	DISK		RIM		BLADE			
	TF	UCF	TF	UCF	TF	UCF	TF	UCF
FAN	1	1	0	0	14	6	15	7
COMPRESSOR	7	7	4	3	45	4	56	14
TURBINE	5	5	2	1	46	8	53	14
TOTALS	13	13	6	4	105	18	124	35

TF - TOTAL FAILURES

UCF - UNCONTAINED FAILURES



**FIGURE 2**

# THE INCIDENCE OF ROTOR FAILURE IN COMMERCIAL AVIATION ACCORDING TO ENGINE TYPE AFFECTED - 1971

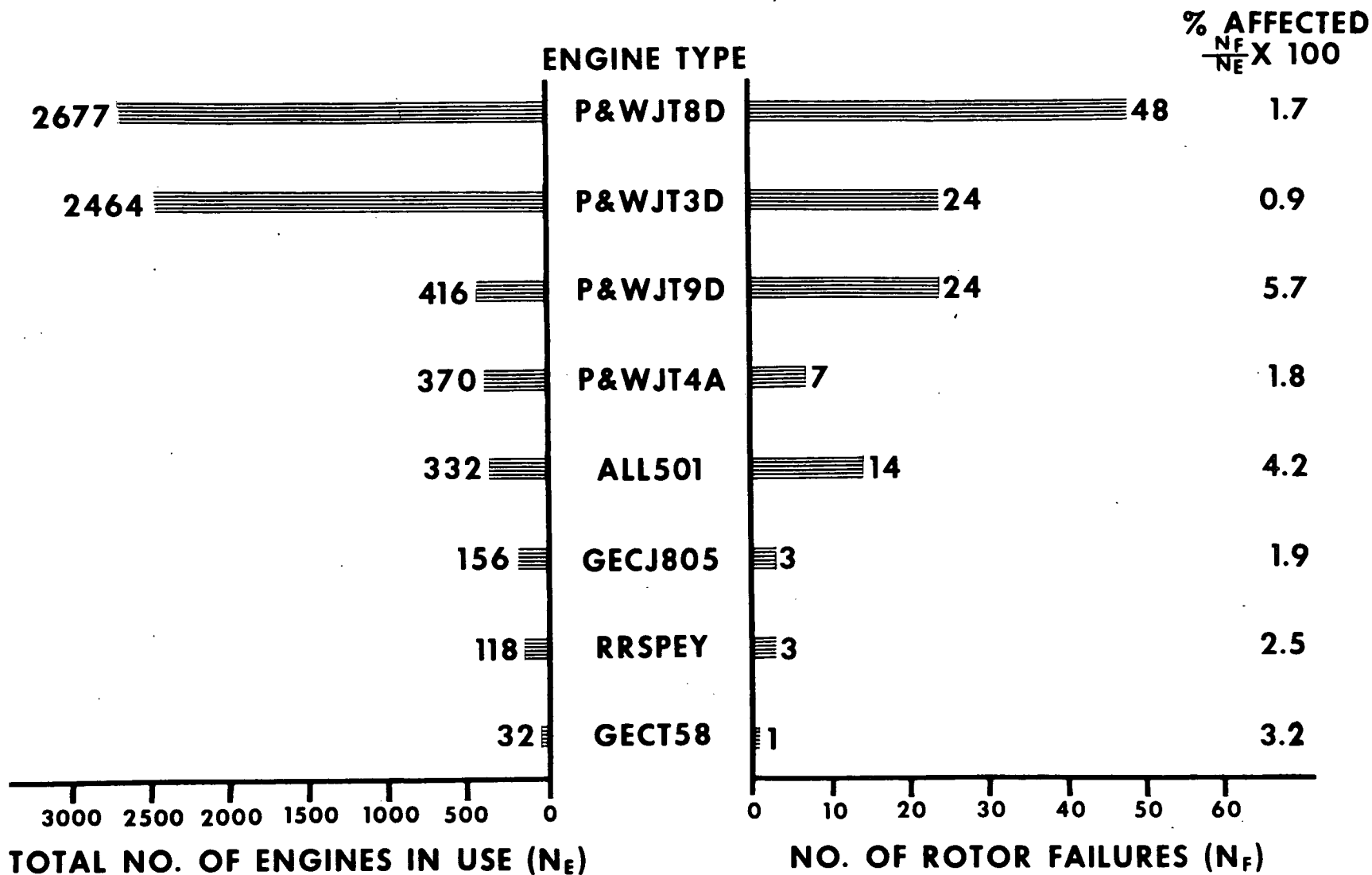


FIGURE 3

# ROTOR FAILURE CAUSE CATEGORIES - 1971

DESIGN & LIFE  
PREDICTION PROBLEMS  
(LCF, VIBRATION, ETC.)

SECONDARY CAUSES  
(BEARING, STATOR,  
SEAL FAILURES, ETC.)

FOREIGN OBJECT  
DAMAGE

QUALITY CONTROL  
(MATERIAL,  
MACHINING, ETC.)

OPERATIONAL  
(OVERTEMP,  
OVERSPEED, ETC.)

ASSEMBLY OR  
INSPECTION ERROR

UNKNOWN

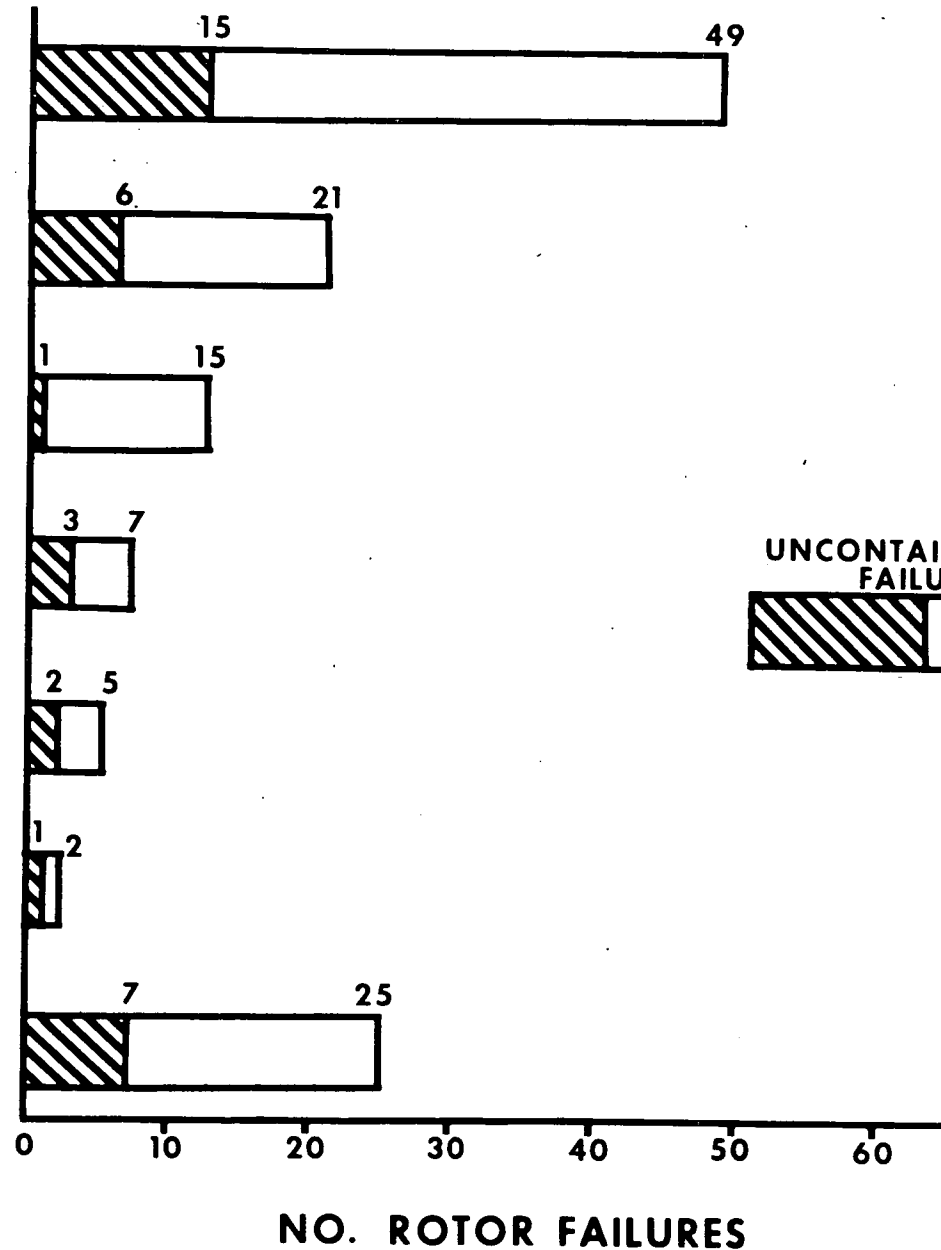


FIGURE 4